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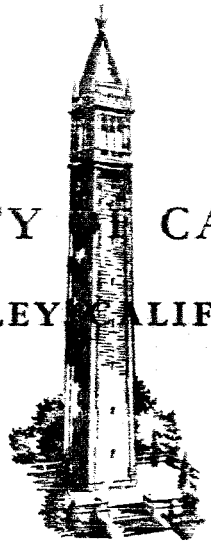

UNIVERSITY OF CALIFORNIA

BERKELEY CALIFORNIA

Space Sciences Laboratory
University of California
Berkeley 4, California

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Biochemical Activities of Terrestrial Microorganisms in Simulated Planetary Environments

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BIOCHEMICAL ACTIVITIES OF TERRESTRIAL MICROORGANISMS IN SIMULATED PLANETARY ENVIRONMENTS

Introduction:

The biological contamination of the moon and planets by terrestrial microorganisms has been the primary question around which much of our research is centered. During recent months we have conducted additional experiments concerned with extremes of temperature and other environmental parameters that might serve as possible restraints to the development of microorganisms on the nearby planets. The results of these experiments and related studies in progress are summarized below.

A. Microbiological Studies:

1. Preliminary experiments were designed to select for microorganisms indigenous to terrestrial soils which are capable of surviving the diurnal temperature variations characteristic of the average martian environment. The results of the experiments to date provide evidence for survival of a variety of microbial types in their native soil environment as well as in artificial media exposed to temperatures from ca 200 to 300°K. A report on the microbiological aspects of the contamination problem is being prepared for publication.

2. We have initiated exploratory experiments to determine possible survival of terrestrial microorganisms following exposure to temperatures approaching those of the lunar surface. Spore-forming bacteria capable of withstanding 10^{-8}mm Hg were recovered from soil samples maintained under anaerobic conditions at 373°K. Other experiments in progress are designed to study the effect of lunar temperature variations on terrestrial microorganisms.

3. The microbiological studies relating to planetary environments lacking molecular oxygen have advanced along several fronts. One phase of this research is concerned with photometabolism of organic substrates under conditions of oxygen deprivation. To clarify the relationship between light-dependent processes such as photo-assimilation, photoreduction and photorespiration, we are presently engaged in a comparative study of photosynthetic bacteria and algae.

The development of selective culture techniques for the isolation of microorganisms dependent upon light for their growth in the absence of

atmospheric oxygen was discussed in a paper submitted for publication in a symposium on marine microbiology. The paper describes details of the isolation procedure and outlines some observations on the appearance of new vitamin requirements for growth at supra-optimal temperatures. Reprints of this paper will be forwarded as soon as they become available.

4. Studies on the lability of the photosynthetic apparatus in algal flagellates and higher plants have served to focus attention on the problem of genetic autonomy of chloroplasts and symbiotic origin of photosynthetic forms in nature. The permanent loss of ability to produce functional chloroplasts following growth of sensitive strains at supra-optimal temperatures, exposure to sub-lethal doses of ultraviolet light, or treatment with certain chemical agents, has led to the hypothesis that these agents act on a class of molecules that carry genetic information. Experiments are in progress to determine how these environmental factors interact in controlling the heredity of the chloroplast in photosynthetic microorganisms. To distinguish between chloroplast as organelle versus endosymbiont, several algae are being examined for differences in DNA base ratios between the photosynthetic and nonphotosynthetic members.

B. Investigations in Planetary Astronomy:

1. An unsuccessful attempt to identify the organized element type 5 of Nagy and Claus as a terrestrial pollen contaminant was reported as an appendix to an article by Harold C. Urey in Science 137:623 (1962). Drs. H. G. Baker and Carl Sagan attempted an identification of a type 5 organized element as the pollen of the evening primrose. It has very recently been shown by Fitch and Anders that the organized element type 5 is in actuality a ragweed pollen grain.

2. A paper closely related to the main objective of this grant, "Microenvironments for Life on Mars," by Joshua Lederberg and Carl Sagan, has been published in Proc. Nat. Acad. Sci. 48:1473 (1962). This article suggests that despite the rigors of the average Martian environment, there may be microenvironments which are much more equable for familiar terrestrial organisms. If these postulated microenvironments indeed exist, then the environments being used in our laboratory simulation studies may actually be harsher than some which exist on Mars.

3. The paper "Structure of the Lower Atmosphere of Venus," by Carl Sagan, has been published in Icarus 1:151 (1962). The biological relevance of this work is twofold: first, it strongly suggests that the surface temperatures and pressures are both too great to support familiar forms of terrestrial life; secondly, the suggestion has been made in this work that these same pressures and temperatures may lead to the high pressure synthesis of organic compounds near the surface, provided that there exist small amounts of hydrogen-containing molecules, such as water, near the surface. The organic compounds synthesized must have relatively low vapor pressures, because all spectroscopic searches for simple hydrocarbons and other elementary organic molecules on Venus have been negative.

4. A discussion by Carl Sagan of the nature of the Great Red Spot will be published in the Proceedings of the 11th International Astrophysical Colloquium in Liège. This paper shows that the idea of a solid Red Spot floating in a liquid or gaseous medium is untenable, and that Hide's meteorological explanation of the Red Spot as a Taylor column is probably correct. Observations of mass exchange between the Red Spot and the surrounding atmosphere show that the Taylor column is not stagnant, and therefore that mass exchange occurs also between the top of the Red Spot and the depths. The suggestion is then made that the color of the Red Spot is due to organic material characteristic of considerable depths in the Jovian atmosphere being transported convectively to the top of the atmosphere. Reprints of this paper will be forwarded to NASA when they become available.

5. A paper entitled "Direct Contact Among Galactic Civilizations by Relativistic Interstellar Spaceflight," by Carl Sagan, is in press in Planetary and Space Science, scheduled for publication in the April issue. Reprints of this paper will be forwarded to NASA as soon as they become available.

6. Two papers by Carl Sagan, Cyril Ponnamperuma and Ruth Mariner, soon to be published, are "Formation of Adenosine by Ultraviolet Irradiation of a Solution of Adenine and Ribose," to be submitted to Nature; and "Ultraviolet Synthesis of Adenosine Triphosphate Under Possible Primitive Earth Conditions," probably to be submitted to the Proceedings of the National Academy of Sciences. This research was

conceived while Dr. Sagan was still at the University of California, Berkeley, and working under the present contract. Its execution, however, occurred after Dr. Sagan left Berkeley.

Dr. Carl Sagan has now left northern California. His present address is:

Department of Astronomy
Harvard University
Cambridge 38, Massachusetts

and

Smithsonian Astrophysical Observatory
60 Garden Street
Cambridge 38, Massachusetts.

He is, however, continuing his participation in this project, especially in those phases concerning simulation of extraterrestrial environments and inoculation of these environments by terrestrial microorganisms.